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B70 06063

SUBJECT: Atmospheric Science Experiments for Mariner Mars '71
Case 235

DATE: June 24, 1970

FROM: E. N. Shipley

ABSTRACT

Five potential atmospheric science experiments for the Mariner Mars '71 mission are described. The experiments are:

1. Study of the thick haze that was suggested by the Mariner IV data
2. Study of the thin haze seen in the data from Mariners 6 and 7
3. Determination of the atmospheric density profile of Mars through analysis of Rayleigh scattering
4. Measurement of the elevation profile of the planet by comparison of the atmospheric density at various places.
5. Monitoring of the camera performance.

The thick haze study has been retained despite the lack of evidence for such a haze in the results of Mariners 6 and 7. Because of its uncertainty, this experiment should be assigned low priority in mission planning.

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DATE: June 24, 1970

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MEMORANDUM FOR FILE

I. Background

The pictures returned from Mars by the 1964 Mariner IV mission showed a bright atmosphere extending in excess of 150 km above the limb of the planet, and also indicated very little contrast on the surface of the planet. These unexpected phenomena can be accounted for by a haze having an optical thickness of 0.4, measured vertically(1). On the other hand, it is also possible that these phenomena arose from a malfunction in the spacecraft or in the camera subsystem.

The presence of a haze of the thickness suggested by the Mariner IV data would have substantial effects on other missions to Mars. One of the major goals of the Mariner '71 mission is to study time varying features on the surface of Mars. Since such changes are detected as albedo variations, accurate photometric measurements of the surface are required, and corrections for any effects such as haze are essential if useful data are to be obtained.

Bellcomm submitted a proposal to participate in the Mariner '71 mission, for the purpose of studying the photometric properties of haze in the Martian atmosphere. Since the time when the proposal was submitted to NASA, several new ideas for experiments in the general area of atmospheric science have been developed. It is the purpose of this memorandum to describe these experiments in order that the mission planning activities related to the Mariner '71 mission can take them into account.

There are at least two factors which have led to the development of the new experiments. These are as follows:

1. Mariners 6 and 7 did not detect any hazes as thick as those postulated to explain the Mariner IV data, save for the polar regions. This lends credence to the viewpoint that the anomalous results from Mariner IV can be attributed to a malfunction in the spacecraft or the camera subsystem. Mariners 6 and 7 did detect thin hazes, but they do not have an optical thickness great enough to create perceptible effects on vertical photography of the surface(2). If there are not thick hazes above the regions of interest, the original experiments suggested by Bellcomm need not be carried out.

On the other hand, it remains possible that the anomalous photometric results of Mariner IV are real, and that Mars is subject to periods in which it is covered by a thick haze, while at other times it is free from the haze.* For this reason, the thick haze studies cannot be completely ignored in mission planning.

2. The techniques that have been developed to deal with the thick haze can be carried over to study Rayleigh scattering in the Martian atmosphere with a minimum of difficulty. Such studies will enable quantitative determinations of the density profile of the atmosphere to be made.

Because of the Mariner 6 and 7 results, it is not believed at this time that Mariner '71 will encounter thick hazes. Consequently, the major emphasis in mission planning will center on the alternate experiments proposed in Section III.

In this memorandum, we will discuss only those experiments that are the direct concern of the Mariner '71 group at Bellcomm. There are other experiments in the area of atmospheric science that will be conducted during the mission by other investigators. Among the currently planned studies are investigations of clouds, particularly their behavior as a function of time, and of various dirunal changes in surface brightness, which may arise from atmospheric phenomena.

II. Description of Mariner '71 Cameras and Missions

Camera Subsystem

Each Mariner '71 spacecraft will carry two cameras into orbit about Mars, one having a wide angle field of view (A camera) and the other a narrow field of view (B camera). The A camera has a 50 mm focal length and a field of view that is 11° by 14°. Each A camera is equipped with a filter wheel having eight positions. The filters consist of four narrow-passband spectral filters, three polarization filters, and a filter (minus blue) to match that of the second camera, which has only a single filter. The shutter speed is adjustable from 3 ms to about 6 seconds exposure, in factors of two.

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* The haze postulated to explain Mariner IV data is not so thick as to obscure the surface markings, although it would decrease the contrast between the bright and dark areas. If the haze is a transient phenomenon, it is possible that earth-based observers would ascribe the lack of contrast to poor seeing conditions through the earth's atmosphere.

The B camera has a focal length of 500 mm, and a field of view that is 1.1° by 1.4°. It has a variable shutter speed with the same range as that for the A camera.

For each spacecraft, the two cameras are bore sighted and mounted on a scan platform that is used to point the cameras within the limits imposed by the spacecraft structure. The spacecraft orientation is fixed through reference to the sun and to Canopus. The exact range of directions accessible to the cameras cannot be simply described, but in general, they can only be pointed into the hemisphere away from the sun. However, they cannot be pointed closer than 15° to the anti-solar direction.

The cameras use slow scan vidicons to convert the picture to an electronic signal. It requires about 42 seconds to read out a single picture. The data are digitized during readout and stored on a magnetic tape, which has a capacity of about 30 pictures. These factors, together with the limited data rate between Mars and the earth, restrict the flexibility of the mission and require that careful planning be carried out in order to optimize the information returned from the spacecraft.

Orbit Selection

The Mariner '71 mission consists of two identical spacecraft. In order to accommodate different experimental objectives, it is planned that the two spacecraft will be placed in substantially different orbits.

The A mission is designed to map a large portion of the Martian surface. The period of the orbit is 12 hours, synchronous with the earth's rotation. The phasing is adjusted so that every second periapsis occurs within view of the 210 ft. receiving dish at Goldstone. This method allows the return of the greatest number of pictures.

The orbital period of the A mission is slightly less than one-half of the rotational period of Mars. As a result, alternate periapses do not recur over the same surface area but are displaced by about the width of one A camera frame. Thus contiguous coverage of the surface is possible. Periapses recur over previously photographed areas after a lapse of about 20 days.

The B mission has been designed primarily for the study of variable features. In addition, its high apoapsis provides a convenient opportunity for synoptic photography. The requirements for study of the seasonal surface variations are that the same region be photographed under the same lighting conditions every few days. Changes in lighting might mask any changes in the surface albedo. The orbital period has been chosen to be approximately 4/3 of the Martian day.* Because of this choice, successive periapses are located over three different regions of the Martian surface, the regions being spaced uniformly about the planet. Every fourth day (three revolutions) the spacecraft returns to photograph a region seen previously. The photography with constant lighting conditions does not occur at periapsis, but rather about one hour before periapsis. The choice of time of photography must be carefully adjusted to minimize changes in lighting over the duration of the mission (90 days).

III. Atmospheric Science Experiments

This section contains a brief summary of experiments that the Mariner '71 group at Bellcomm currently plans for inclusion in the mission. The operational requirements of the experiments have been emphasized because of the necessity of developing mission plans at this time. The descriptions of the experiments are not uniform in their completeness. The last two experiments (D, Altitude Profile, and E, Monitoring of the Camera Performance), in particular, must be regarded as somewhat tentative and subject to evolution from their present form.

A. Thick Haze. The object of this study is to determine the photometric properties of thick hazes. The primary purpose is to provide a basis for correcting photometric measurements taken for such purposes as the measurement of surface albedo variations.

This study requires two principal types of measurements: photography of the limb over the region for which photometric corrections to vertical photographs are to be made, and vertical photographs near the terminator. The limb photographs in the region of interest are intended to be made routinely in conjunction with vertical photographs of the region in order to monitor the status of the haze. The vertical terminator photography provides data on the structure of the haze and, provided the haze is reasonably constant with time, need be repeated only about once per week. It is anticipated that these pictures would be obtained on the B mission.

The Mariner '69 mission did not detect thick hazes in the latitude bands where interest will be centered in '71. Consequently, the existence of the haze, which is based on anomalous results from Mariner IV, is questionable, and these studies should not be incorporated in the primary mission plans. However, it is

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* The period differs from an exact 4/3 multiple in order to compensate for lighting changes caused by the motion of Mars about the sun and by the expected orbital precession.

essential that Science Links* for these studies be developed so that the haze studies can readily and rapidly be incorporated into the mission sequence should the presence of a thick haze be detected.

B. Thin Haze. The purpose is to study in greater detail the thin hazes first detected by Mariner '69. At this time, the most relevant aspects of the haze appear to be its distribution above the surface of the planet, and its temporal variation. Presumably, temporal variations may arise either from a motion of the material constituting the haze, or by a loss (or accretion) of material constituting the haze.

The haze is itself an interesting phenomenon. Moreover, it is hoped that a detailed characterization of the haze, including its regional and temporal variations, will provide useful information on other meteorological occurrences, such as upper atmosphere winds.

The thin haze can be seen only above the limb of the planet; the thin hazes detected by Mariner '69, which have an optical thickness estimated[2] to be 0.01 (vertically), would not produce a measureable effect on vertical photography. The visibility of the haze when it is seen above the limb is enhanced because it is viewed against the dark background of space rather than the lighted surface of the planet, and because of the greater apparent optical thickness when the line of sight passes tangentially through the haze[3].

Unfortunately, pictures above the limb provide data on the haze only above a limited strip of surface lying along the limb. In order to map the regional extent of the haze, it is necessary to take repeated photographs as the orbital motion of the spacecraft brings new regions of the planet onto the limb seen by the spacecraft.

It does not seem likely that it will be possible to take enough pictures to characterize completely the thin haze on a planetwide scale. The synoptic pictures, which are taken near apoapsis of the B mission orbit, will provide useful data at the beginning of the mission. Changes in the lighting geometry will degrade this mode in a period of about two weeks, and it appears that subsequently it will be possible to devote only a

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* Science Links are spacecraft operational plans designed by JPL to carry out a specific experiment.

few pictures each orbit to the study of the thin haze. Pictures from both the A and the B missions will be useful. These pictures must be utilized carefully if a general characterization of the haze is to be obtained. This also implies that there must be a great emphasis on real time mission planning so that the available pictures are directed to the regions of greatest interest - boundaries of the haze and areas of temporal variation.

The study of the haze will be conducted at two separate levels. First, there will be a general study of the morphology of the haze, especially with a view toward correlating the haze with other meteorological or surface phenomena. Second, there will be a quantitative study of the haze aimed at determining the scattering phase function and the brightness and structure of the haze. Knowledge of these parameters may lead to an understanding of the physical properties of the scattering particles.

C. Gaseous Atmosphere. The structure of the gaseous atmosphere can be studied by analyzing the brightness of the light scattered by the atmosphere. For Mars, the atmosphere is so thin that it produces no measurable effect on photographs taken vertically through the atmosphere, but, when it is seen above the limb, the atmosphere produces a brightness measurable by the camera to an altitude of perhaps 50 km above the limb. A preliminary study of this method of investigating the atmosphere has been reported previously[(3)]. The required measurements can be carried out on both the A and the B missions.

In order to make satisfactory measurements, it is essential that the region photographed be free of haze. Furthermore, the phase angle at the limb should be near zero degrees.* This condition maximizes the Rayleigh scattering and places the limb near the terminator where the surface brightness is low. The latter result means that light scattered from the surface will have a smaller effect on the atmospheric brightness than would occur over more brightly illuminated areas. This will increase the accuracy of the analysis because the reflecting properties of the surface, which are not well known, will not enter strongly into the calculations.

At the chosen target, six pictures should be taken in rapid sequence. Four A camera frames are taken, one frame through each of the four spectral filters on the camera. Two high resolution B frames are taken to provide detailed data on the structure of the atmosphere. These two frames are taken at different exposure settings in order to increase the brightness range over which useful measurements can be made.

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* As noted above, spacecraft constraints on the camera pointing direction limit the optic axis of the camera to phase angles greater than 15°.

The four A camera frames can be used to estimate the spectrum of the scattered light as a function of height above the surface. Rayleigh scattering has a characteristic inverse fourth power wavelength dependence which can be used to distinguish those areas where Rayleigh scattering predominates. Close to the surface, dust or aerosols may contribute to the intensity of the scattered light. Their presence can be detected by a deviation from the Rayleigh wavelength dependence.

D. Altitude Profile. Recent radar data[4] have indicated that the surface of Mars has a relief of at least 15 km. To the surprise of some observers, the data did not yield a direct correlation between surface brightness and elevation. It is, of course, of major interest to determine the elevations of the various features on Mars, since the elevation may be an important parameter in determining which physical processes operate in a specific region.

Limb pictures can provide a measure of the pressure altitude of the surface region at the limb. The atmospheric pressure at the surface is measured by the brightness of the Rayleigh scattered light. In this way, the relative altitudes of widely separated regions can be compared.

The measurement for each region requires 5 pictures. Four A camera frames, taken through the spectral filters, provide information to insure that Rayleigh scattering is dominant, and a single B camera picture is used to provide detailed brightness data. These measurements may be obtained on both the A and the B missions.

E. Monitoring of the Camera Performance. There is evidence to indicate that the vidicon tubes which will be flown on Mariner '71 are not exceptionally stable[5]. Instability in brightness response is a common problem with vidicons. Any instability will make it difficult to calibrate the camera system. This is unfortunate because some of the experimental work in the '71 mission depends upon accurate absolute measurements of scene brightnesses.

It may be possible to calibrate the B camera during the mission by observing Saturn and measuring its brightness.* Numerous pictures may be required to obtain an adequate calibration. It is currently planned that this procedure be carried out only two or three times during the course of a mission.

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* This technique has been suggested by B. A. Smith, New Mexico State University.

Because the camera calibration is so suspect, it is desirable to monitor the camera calibration on a continuous basis. It appears that this can be accomplished by routinely measuring the atmospheric brightness above a specific region of the surface. It is assumed that the atmosphere is stable over periods of one earth month. Seasonal effects, such as changes in the quantity of atmospheric material stored in the polar caps, may cause significant changes in the atmosphere, but this would be a slow change on the time scale of the mission. It is also important that the same region of the planet be measured each time to insure against confusing brightness changes with altitude changes. This is only possible with the B mission, which returns to the same region every 4 days (3 revolutions). The method is not applicable to the A mission, which is designed to cover new regions of the planet each revolution.

The atmospheric brightness measurement should be carried out once each revolution near in time to other pictures where absolute calibration is critical. For the B mission, the data would be compared with similar data from pictures taken 3 revolutions later. Three pictures would suffice: two A camera pictures through different filters to provide spectral data, and a B camera frame for intensity data. It is important that these data be analyzed in near real time so that any apparent anomaly in the brightness measurement can be immediately investigated.

E N Shipley

1014-ENS-bmn E. N. Shipley

Attachment
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